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TITLE: Physiological and Clinical Findings During Latent Hypxia in the Hypobaric Chamber

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Physiological and Clinical Findings During Latent Hypoxia in the Hypobaric Chamber

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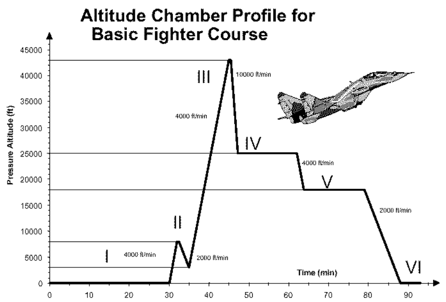
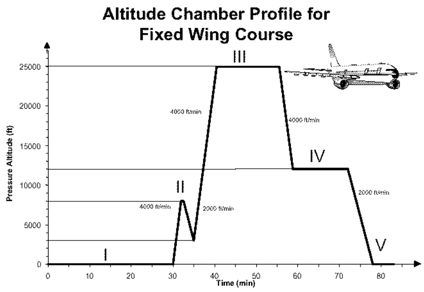
Introduction:

Since 1995 the hypobaric training of aircrew, in accordance with STANAG 3114, is performed in the highly sophisticated air conditioned hypobaric chamber of the German Air Force Institute of Aviation Medicine, Division II at Koenigsbrueck, Germany. It is a main part of overall 150 Physiological Training Courses per year.





Method:

Integrated in well known chamber profiles, demanded in the STANAG 3114, additional exposures in different pressure altitudes can be performed. Routinely six trainees, accompanied by one medical safety attendant, are monitored continuously by ECG, heart rate, breathing cycle, and oxygen saturation during their entire stay in the chamber. They will experience pressure breathing, starting at the pressure altitude of about 28.000 ft during the ascend of the chamber profile. Besides the mandatory demonstration of acute hypoxia at a pressure altitude of 25.000 ft there is a second demonstration of critical hypoxia at a pressure altitude of 18.000 ft for fighter aircrew and of mild hypoxia at 12.000 ft for transport aircrew during hypobaric chamber training.

At a pressure altitude of 25.000 ft, where acute hypoxia occurs, the trainees of basic courses should learn to experience at least one, or two of their personnel oxygen deficiency symptoms. They will have to recognise these symptoms later in the continuation training.

Because of this, it seems to be more important for operational reasons to experience the borderline exposure to hypoxia at the pressure altitude of 18.000 ft. This is the normal pressure altitude in the cockpit of fighter aircraft in flight altitudes above 40.000 ft. Future aircraft will be designed to fly routinely at altitudes up to 50.000 ft or 60.000 ft without full pressure garment. The pressurisation of the cockpit therefore will reach critical low

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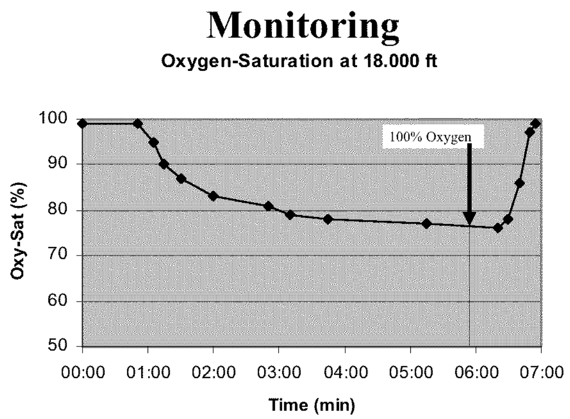
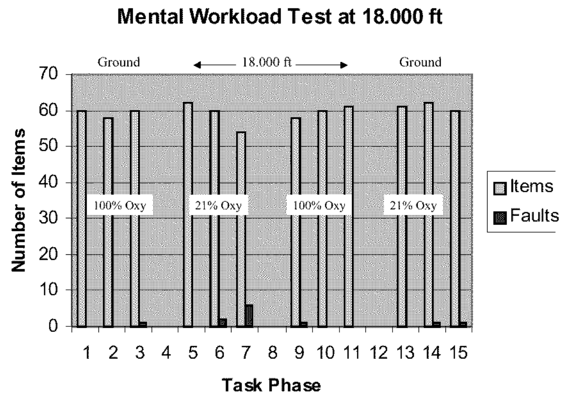
pressure values due to the maximum pressure difference of 5 PSI between the cockpit and the ambient atmosphere. Even short disconnection from the oxygen supply due to poorly fitting masks, leakage in the oxygen delivery system or removal of the oxygen mask will increase the risk of unrecognised hypoxia.

Therefore, in this "normal, operational" maximum cabin pressure altitude trainees perform mental workload tests, simulating normal tasks when flying the aircraft at high altitude, for example during surveillance missions. The mental workload test consists of 3 periods of 90 seconds each, in which the trainees have to calculate numbers. After the introduction and exercise period without data collection during the pre-breathing phase of the chamber training, the first three periods are performed at ground level when breathing 100% oxygen.



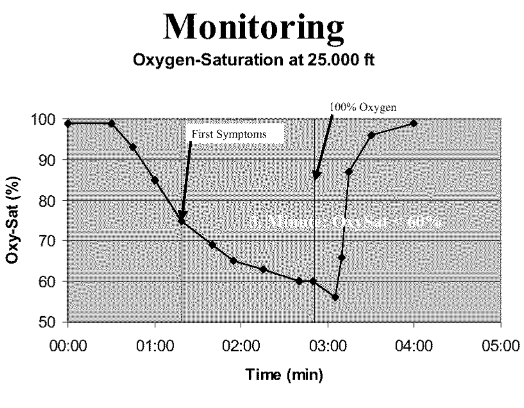


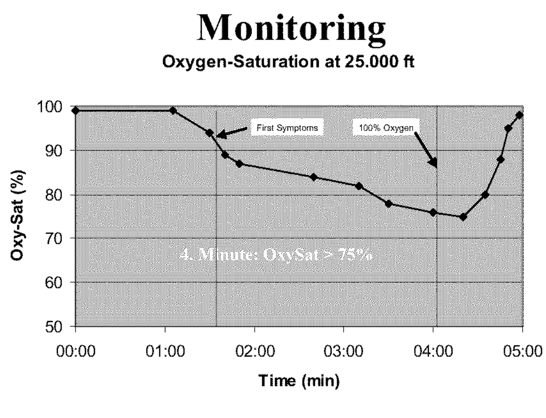
After the demonstration of acute hypoxia at 25.000 ft, the trainees descend to the pressure altitude of 18.000 ft. There they have to disconnect themselves from the oxygen supply. During the following three periods, lasting about five minutes, they are breathing ambient air (21% oxygen). Immediately after the last tasks they experience night vision demonstration in dimmed light, reading low level navigation maps. When connected to the oxygen system and breathing 100% oxygen again, they experience their colour vision deficiencies. In a second sequence they perform the same mental workload, now breathing 100% oxygen, to compare their individual results with the previous test. In addition to the findings of the results of this workload the ECG and the oxygen saturation curve (measured by a pulse oxymeter) will be individually discussed.

Results:

There is a broad variability in physiological responses to the exposure of hypoxia. The reaction of the heart rate varies from

- an ***increase*** up to 50 beats/min within seconds (stress reaction),
- gradual slight ***increase*** (physiological reaction to oxygen deficiency) and
- sudden ***decrease*** of the heart rate (warning symptom of hypoxia-induced loss of consciousness).





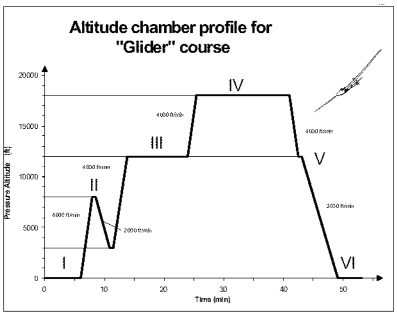
Dependent on gender, body-mass-index, and physical fitness, the time in which the trainees reach a critical oxygen saturation of 70%, varies from 90 seconds up to more than 5 minutes.

The steepness of hypoxia-induced decrease of oxygen saturation, especially during the operational hypoxia exposure at 18.000 ft, might be a symptom not only for individual dispersion but also for latent pathologic reasons. Typically, most of the trainees do not recognise hypoxia symptoms during their hypoxia exposure at 18.000 ft by themselves when distracted by the mental workload tests.

Some trainees re-connect themselves to 100% oxygen supply during the acute hypoxia exposure at a pressure altitude of 25.000 ft within less than 60 seconds, reaching an oxygen saturation level of 90% to 80%. But when distracted by mental workload at the pressure altitude of 18.000 ft breathing ambient air, they often do not feel hypoxia symptoms, although their oxygen saturation went down to 75% to 70%. The typically slower decrease in oxygen saturation might hinder the trainee to identify oxygen deficiency symptoms. During acute hypoxia at a pressure altitude of 25.000 ft an oxygen saturation level of 75% normally will be reached within one minute. While staying at a pressure altitude of 18.000 ft oxygen saturation decreases to 75% normally within 5 minutes. This might be explained by the comparison with the example: During sunset you may read a newspaper down to a very low ambient illumination. This will be recognised immediately after the light is switched on. In the same ambient illumination it might be impossible to read the newspaper, if the light previously was switched on. Human individuals may not recognise slow changes in their environment.

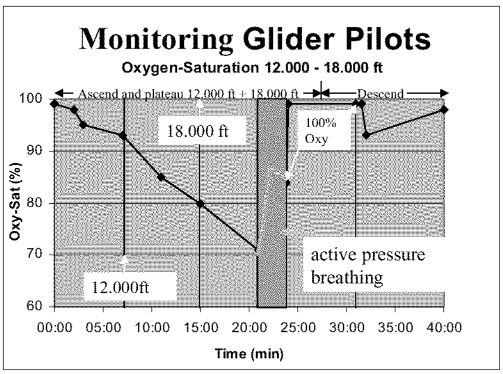
Lesson learned: The training results show the importance of situational awareness, when flying at altitudes, where the cockpit pressure altitude is above 12.000 ft. Situational awareness in this case means: watch your oxygen and cockpit pressure instruments during the cross checks, do not forget the PRICE-check. If this would kept in mind, a fatal accident, like the one of the crashed Lear Jet after a 5 hour ghost flight in October 1999 might have been avoided.

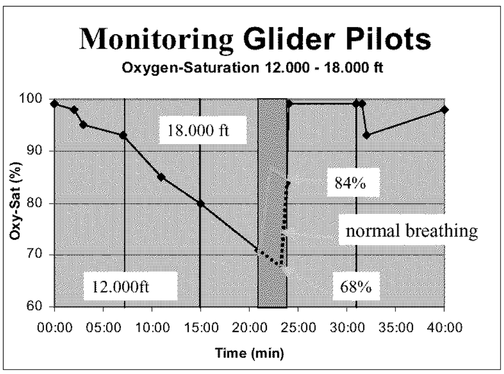
Active positive pressure breathing, performed as M-1 manoeuvre or Valsalva manoeuvre, increases the oxygen



saturation of the blood. The effectiveness of this method can be shown in the following example. At the pressure altitude of 18.000 ft, breathing ambient air (21% oxygen), the trainee reached an oxygen saturation of 70% . With active pressure breathing, the trainee is able to increase his oxygen saturation up to 84%. With this strength consuming breathing technique the evident higher oxygen saturation level can be stabilised up to about 60 seconds.

Without the pressure breathing technique the trainee would have reached 68% oxygen saturation in the same time.





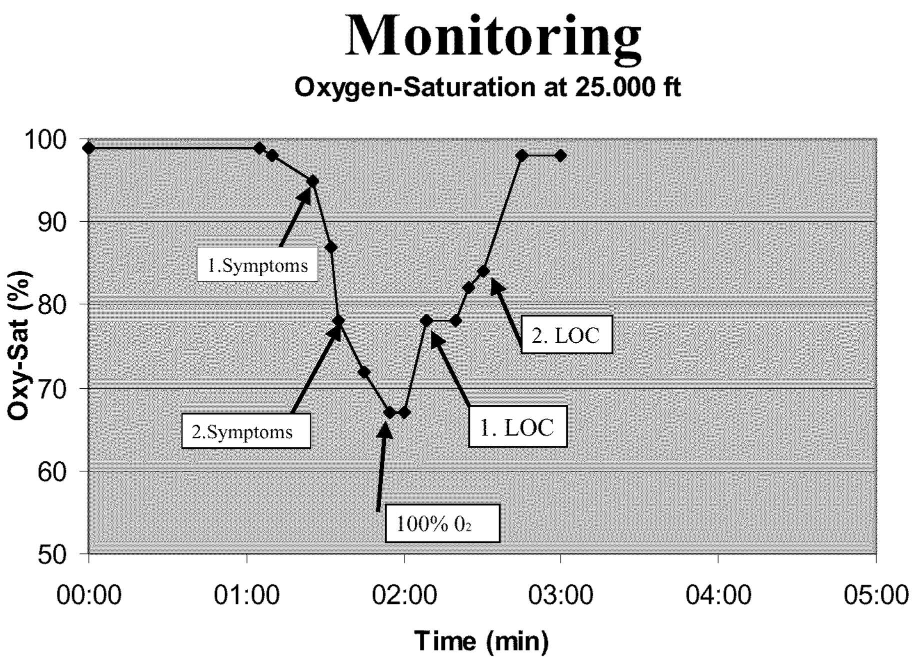
Other experiments showed, that it is important to reach safe pressure altitudes – or connection to a full bottle of oxygen – when performing this pressure breathing technique. We found, that the oxygen saturation of the blood decreases rapidly to a very low saturation level, when the trainee stopped the pressure breathing technique.

Therefore this technique should be used only as an emergency method when flying at high altitudes without sufficient oxygen supply.

Clinical aspects:

In former times - without any medical monitoring during physiological training in an altitude chamber - loss of consciousness occurred more than sporadic. Routinely these episodes were explained as a response to hypoxia only. Now - with the medical monitoring - we are able to differentiate between the reasons for loss of consciousness and even for imminent loss of consciousness.

The examples above underline, that it is an advantage to recognise signs of imminent hypoxia-induced loss of consciousness, even when the monitored oxygen saturation of the blood is greater than 75%. The sudden decrease of the heart rate during hypoxia exposure is a is typical omen of cardiac disturbance, presenting as bradycardia or even asystole.



Conclusion:

Biomonitoring during physiological training is not only helpful for the trainees' feedback by adding objective findings and numbers to subjective symptoms during acute and mild hypoxia, but also helpful for the safety crew of the hypobaric chamber to realise health problems of the trainees early enough.

Last but not least: pathological reactions and monitored findings in cardiac parameters are helpful to decide who should be examined further by a cardiologist. In addition, if for pulmonary reasons grounded aircrew should be cleared again for flying duty (waiver policy), monitored altitude and hypoxia exposure can be used for decision making.